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Thermal/optical study and characterization of a MCP doped with In_2O_3 and $AlCl_3$ for solar use

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Abstract

Thermal insulation is one of the major problems of building comfort. One of the solutions proposed is the use of the latent heat of phase change materials to evacuate the external heat in order to keep it at an adequate temperature in the chamber. In this work, we use the latent heat of a MCP type $C_{25}H_{52}$ pure and doped with two types of dopant In_2O_3 and $AlCl_3$ for the climatic application. We study the effect of dopant nature and doping rate on phase change time, latent heat and mass loss. To improve this time we doped our material with In_2O_3, and $AlCl_3$. The study consists in monitoring the evolution of the phase change time, the flow of the latent heat and the loss of the mass according to the nature of the dopant and the doping rate. A study of the DSC, ATG, FTIR and PL characterization is presented. The study showed that the best dopant for solar insulation is $AlCl_3$ doping.

Keywords: MCP, $AlCl_3$, PL, FTIR, DSC.

1. Introduction

Several works are carried out, on thermal insulation of the building in a material with phase change, either by the improvement of the cooling thanks to the natural or forced convection, or by the absorption of the excess of the external heat, we can quote:
In The work of H. Manz et al. (1997) [1] , they proposed a wall of phase change material, the hydrated salt (melting temperature of 26.5°C) and a TIM. The phase change material transmits the visible spectrum of solar radiation, producing natural light. It is contained in glass bricks. The part of solar radiation in the infrared is stored by the latent heat during the melting of phase change material.

A transparent insulating material is added to the extra thickness of the wall to remedy the losses observed in other types of storage walls.

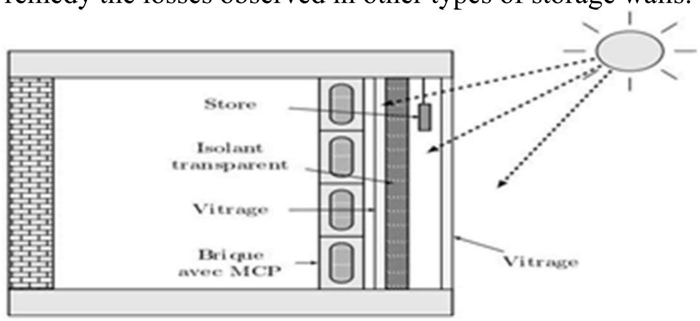

Figure 1.Wall with MCP and TIM.

The authors developed a one-dimensional numerical model coupling conduction and radiation, and compared their numerical results to experiments, using data from a single brick in the middle of the wall in order to avoid edge effects.

In 2004, Mohamed M. Farid et al. [2] present a detailed work of systems using phase change materials (PCM) to store thermal energy in building applications. This review presents the different methods of incorporating phase change materials within the envelope. The conclusion of this work is that the introduction of phase change materials in the building envelope can minimize temperature fluctuations by using solar energy.
An active system was used by Vineet Veer Tyagi and D. Buddhi in 2007 [3] to offload the electrical network during periods of peak consumption, electrical energy is therefore preferentially used during off-peak hours when it is at a lower cost to be stored as latent heat. The principle is to melt or solidify an PCM during off-peak hours in order to solidify it during peak hours and thus restore the heat to the part.

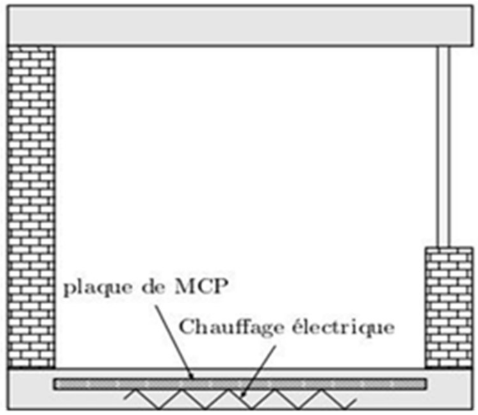

Figure 2. Diagram of underfloor heating

In 2009 Zhu, Ma and Wang [4] focused on work on the dynamic characterization of the behavior of PCMs, necessary to optimize their use on the performance of buildings incorporating phase change materials. The conclusion of this work is that the use of phase change materials can have positive consequences on the energy performance of a building but the heat transfer is sometimes insufficient and the selection of a PCM must be made according to the climate. In which the building is located. However, the studies remain insufficient to correctly predict the possible gains.

The purpose of using these materials is to extend the duration of thermal stability (constant temperature) on the wall beyond 8 hours, which corresponds to the time of sunshine. Unfortunately, paraffin has a low thermal conductivity which does not allow good heat transfer between the material and the ambient air [1-6]. The solution to this problem is the doping of paraffin with fine oxides of high thermal conductivity [5-8]. In recent years, with the development of nanomaterials, studies have begun to improve the thermal conductivity of the base material. by adding nanoparticles, called “nanomaterials”[7-13].

In this paper, we are interested in the influence of doping rate on the phase change time and the latent heat of the material in time and temperature. A thermal characterization (DSC, ATG), optical (PL), spectroscopy (FTIR) and morphology of our materials are studied.

2. Method

In this work, we used a $C_{25}H_{52}$ type paraffin which was doped with In_2O_3 and $AlCl_3$ in the range of 0 and 30% atomic. The material was heated to boiling temperature to obtain its liquid phase using a STUART CC62 hot plate equipped with a STUART SCT1 controller allowing the measurement of temperature as a function of time. The doping agents used are RIEDEL DE HAEM brand In_2O_3 and PRESI brand powdered $AlCl_3$.

Table 1. Characteristics of dopants and MCP

	Density g.cm-^{3}	**Melting temperature °C**	**Molar mass g.mol^{-1}**	**Boiling temperature °C**
In_2O_3	2.44-2.48 g.cm-3	190°Cà 2.5 atm	133.34 g.mol-1	182,7 °Cà 752 mmHg
$AlCl_3$	3.97 g.cm-3	2050°C	102 g.mol-1	2980°C
MCP	0.9 g.cm-3	50-59°C	404 g.mol-1	190°C

3. Results

3.1 Thermal characterization

Figures 5 and 6 shows the influence of doping rate on time as a function of paraffin temperature during the phase change for the two types of dopants.

It is clearly observed that:

The temperature is constant during the phase change period.

The phase change time increases with the doping rate regardless of the type of dopant.

The phase change time evolution is much better for $AlCl_3$ compared to In_2O_3.

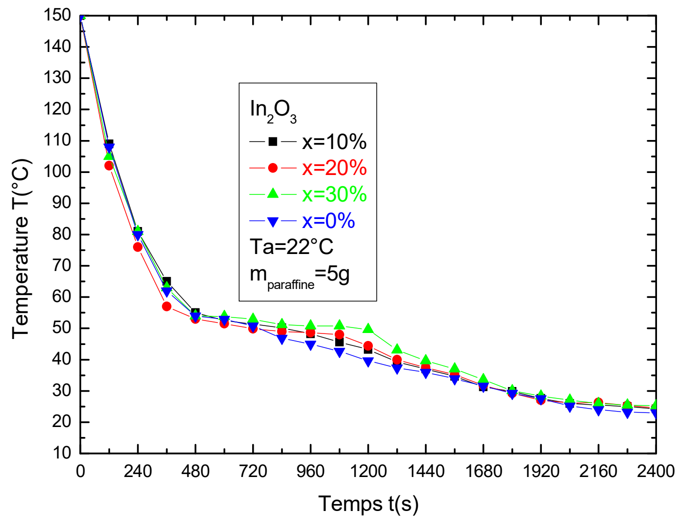

Figure 5.The variation of temperature as a function of time of In_2O_3 for different doping rates of a mass of 5 g.

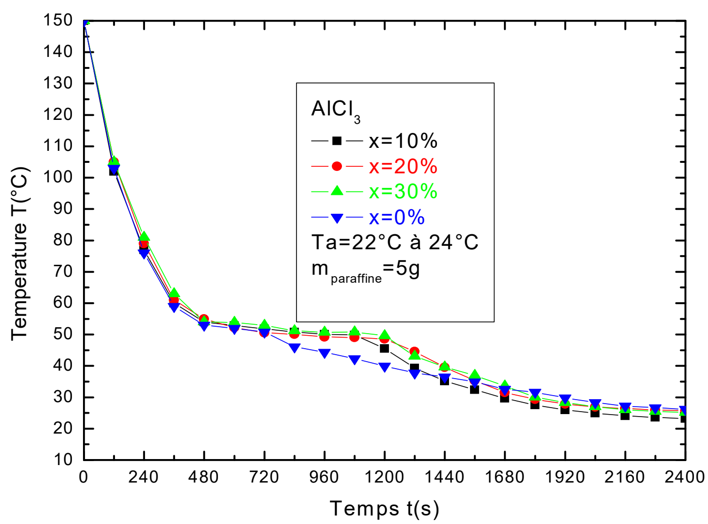

Figure 6.The variation of temperature as a function of time of $AlCl_3$ for different doping rates of a mass of 5 g.

3.2 DSC characterization

The measurement of the heat flow as a function of the temperature of the oven is carried out from the zero temperature 0°C up to the temperature 100°C, with a heating rate equal to 5°C/min.

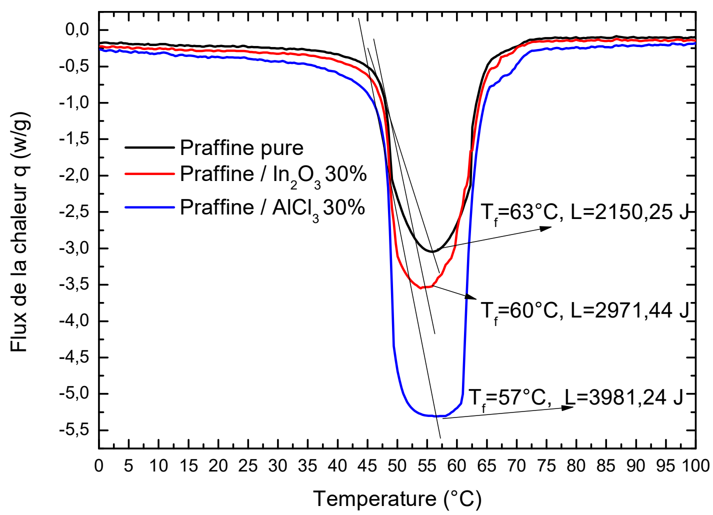

Figure 7. DSC q=f(T) curves of pure paraffin, doped with In_2O_3 and $AlCl_3$ (30%)

This curve represents the heat flux changes of pure paraffin and paraffin doped with In_2O_3 and $AlCl_3$ (30%) and as a function of oven temperature. It is observed that the material begins to absorb heat at the temperature of the beginning of the phase change (45°C, 8.1J/g), where and this is maximum, and then returns to the zero point when it is completely transformed into liquid. The latent heat increases with increasing doping rate for all types of dopants and it is maximum for $AlCl_3$.

The thermal measurement of our material shows that the phase change time enters into the characterization of the heat transfer between the material and the surface of the wall. This time is proportional to the amount of heat transferred and is greater as the doping rate is high.

These results show that there is a relationship between the thermal conductivity and the latent heat when the thermal conductivity is increased with the injection of the nanoparticles, the latent heat increases and increases the phase change time, this study confirms the results obtained on the phase change time calculation.

3.3 Optical characterization

This curve represents the influence of the doping rate on the intensity as a function of the wavelength. It is shown that the intensity decreases with increasing doping rate, which means that both dopants decrease the intensity of the material.

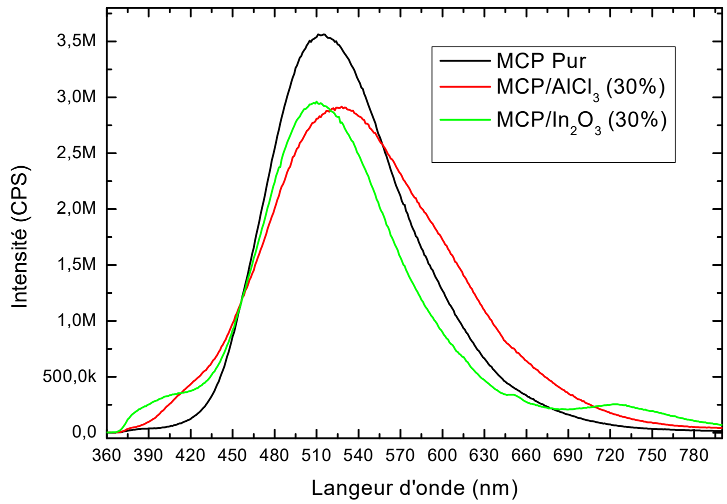

Figure 9. Pure paraffin photoluminescence, paraffin doped with In_2O_3 and $AlCl_3$ 30%

We observe in our figure of paraffin/$AlCl_3$, In_2O_3 and a broad band of absorbance, and this band is very important increases for the doping by $AlCl_3$, therefore our material doped by $AlCl_3$ appears as a suitable material with many favorable properties for solar and nuclear applications. Our spectrum of MCP/ In_2O_3, exhibit two bands of luminescence, a band of short wavelength, located near the absorption edge of the crystal, i.e. the edge luminescence, and another wide band of long wavelength, the maximum of which is generally located in the 430-800 nm spectral range. A strong emission is observed at 450-720 nm associated with the presence of surface defects on the nanoparticles for the two types of dopants. At the same time, an emission peak of 410 nm when increasing the doping rate by 20% for MCP/In_2O_3 nanoparticles gives a gap of 3.1 ev.

5. Conclusion

In this work, we show that the use of phase change materials with high thermal conductivity is a solution for solar cooling and storing energy. The injection of high thermal conductivity nanoparticles of In_2O_3 and $AlCl_3$ improves its thermal conductivity. To see the influence of the doping effect of In_2O_3 and $AlCl_3$ on the paraffin, thermal, optical and spectroscopic characterizations are presented. It is concluded that for all the dopants the doping improves the phase change time and the latent heat. The experimental results show that the use of doped paraffin on the walls of buildings is an effective solution for solar cooling and it is very important in the case of $AlCl_3$ doping.

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